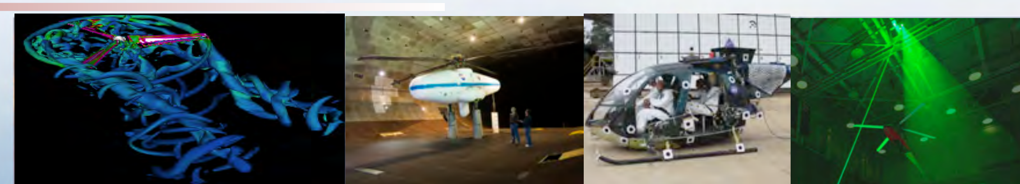
National Aeronautics and Space Administration

NASA Vision for Rotary Wing Propulsion Research



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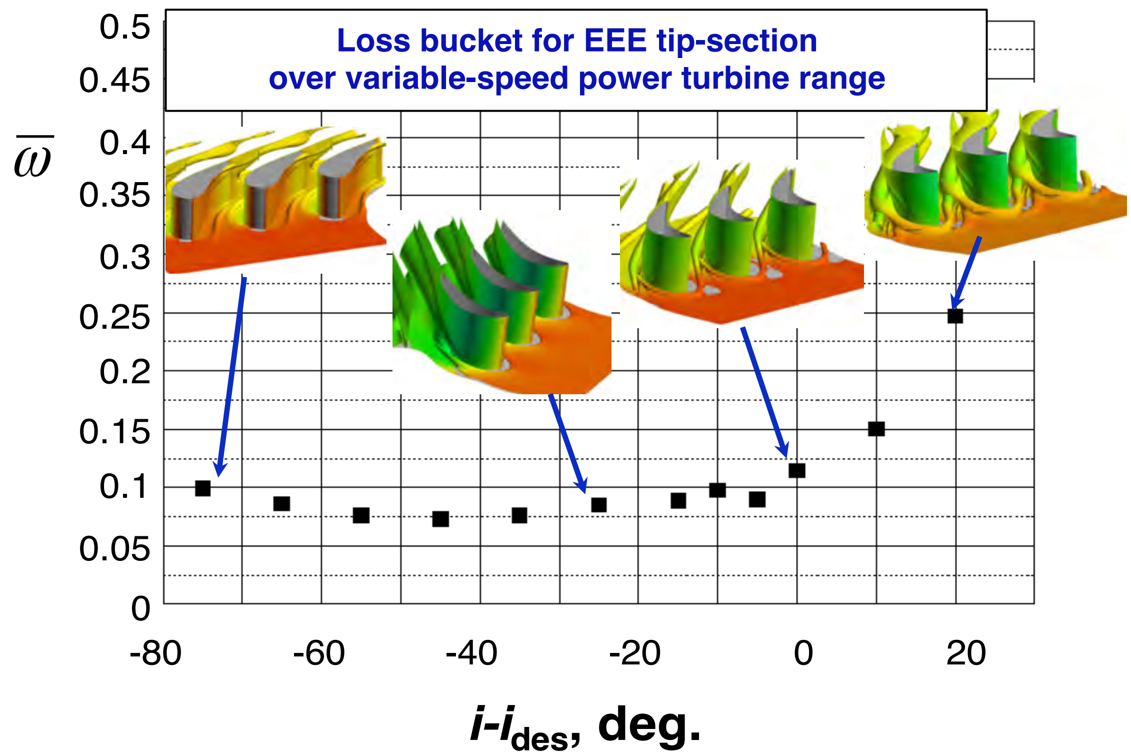
July 31, 2012

Outline

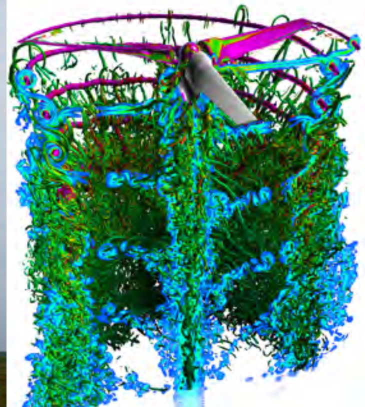
- Overview
- Future Vision for Rotorcraft
- Technical Challenges
- NASA Rotary Wing Project
- Propulsion Research Emphasis
- Concluding Remarks

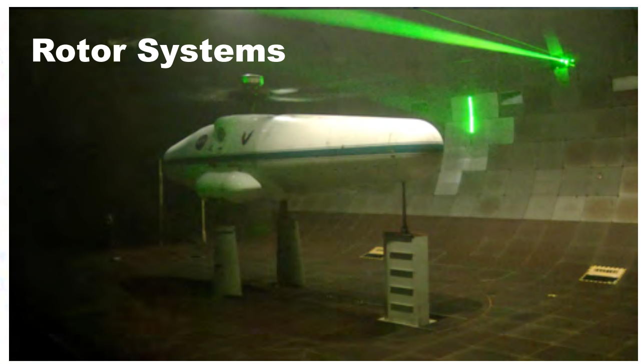


Rotary Wing (RW) Project

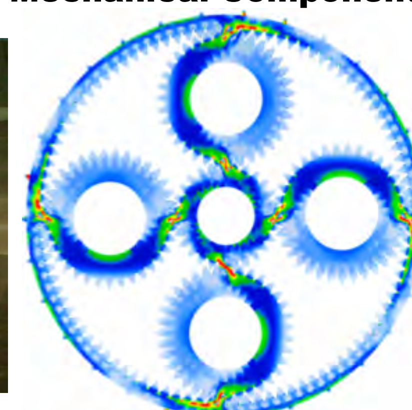
Goal: **Develop and Validate Tools, Technologies and Concepts to Overcome Key Barriers for Rotary Wing Vehicles**

CFD Methods

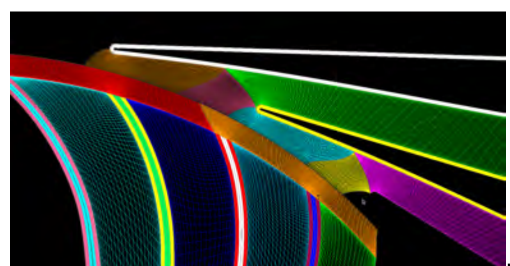




Mechanical Components



Materials & Structures



Engine Research

NASA Rotary Wing Project

Directed to focus on:

– NextGen Rotorcraft Developments
– Mobility / Capacity
– Efficiency
– Energy and Environment

Providing a Vision for Aviation

Challenges for ***commercial*** *rotorcraft with Entry Into Service in 2030*

The Need

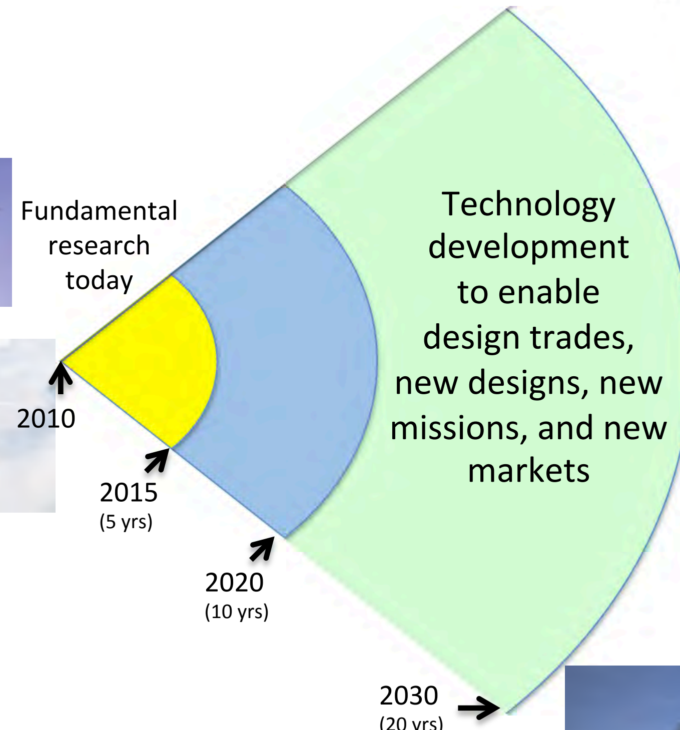
- Identify advanced airframe, rotor and propulsion concepts and enabling technologies
- Guidance for NASA investments in fundamental research

NASA Rotary Wing Approach

- Stimulate thinking in industry and academia on revolutionary aircraft solutions
- Determine high-payoff technologies and research opportunities
- Address performance, efficiency, environmental, and operations goals
- Fundamental Research portfolio robust to many possible futures

NASA Rotary Wing Contribution

- Providing the vision and focus for the fundamental research needed today to **enable the far term outcomes/products, but with near/mid-term impact and technology transition**



Sample Technologies

- Variable speed, high performance, low noise rotor systems
- Efficient engines over wide operating range
- Light weight, efficient drive systems

Providing a Vision for Aviation

*Challenges for **military** rotorcraft with Entry Into Service in 2030*

The Need

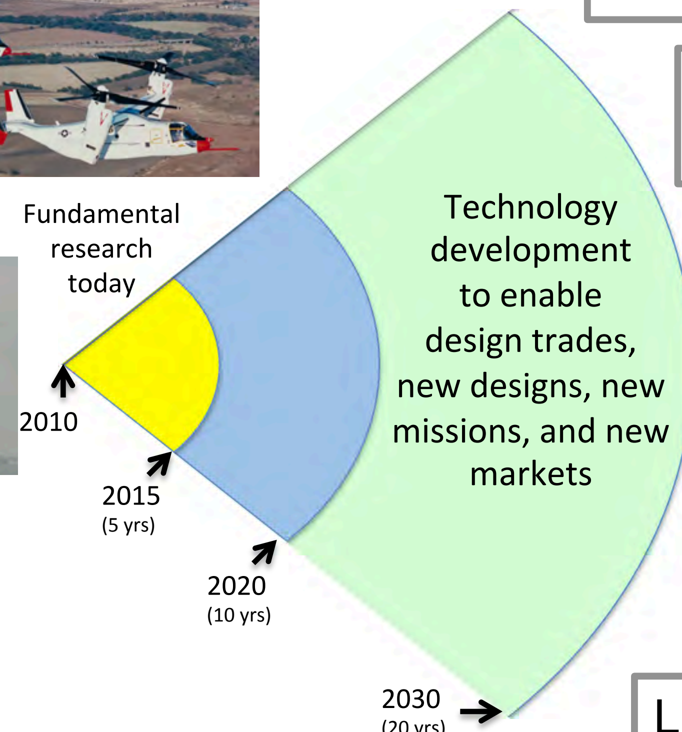
- Identify advanced airframe, rotor and propulsion concepts and enabling technologies
- Guidance for NASA investments in fundamental research with Army partners

NASA Rotary Wing Approach

- **Partner closely with Army for collaborative rotorcraft research**
- Determine high-payoff technologies and research opportunities
- Address performance, efficiency, environmental, and operations goals
- Fundamental Research portfolio robust to many possible futures

NASA Rotary Wing Contribution

- Providing the vision and focus for the fundamental research needed today to **enable the far term outcomes/products, but with near/mid-term impact and technology transition**



Future Vertical Lift

Search and Rescue

Advanced Scout Helicopter

Joint Multi-Role

Utility

Light Attack

Heavy Lift Requirements

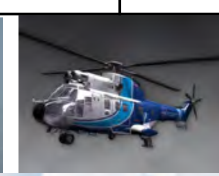
Sample Technologies

- Variable speed, high performance, low noise rotor systems
- Efficient engines over wide operating range
- Light weight, efficient drive systems

Current Common Rotary Wing Configurations and Missions

$6.4B New Civil Purchases in 2012*

1400 New Civil Units in 2012*

	Configurations **(Definition follows DOD convention for rotorcraft)**		
	Light	**Medium**	**Heavy**
Missions	•police •training •traffic/news •power line service •spraying	•police •EMS •traffic/news •tourism •executive •charter service •oil platforms •SAR	•oil platforms •disaster relief •cargo •logging •construction •firefighting
Configurations	 	 	

*From Vertiflite article by Forecast International

Envisioned Common Configurations and Missions in 2030 and beyond

	Configurations (Definition follows DOD convention for rotorcraft)				
	Very Light	**Light**	**Medium**	**Heavy**	**UltraHeavy**
Missions	•surveillance •delivery •spraying •cargo	•police •training •traffic/ news •power line service •spraying •cargo	•police •EMS •traffic/news •tourism •executive •charter •oil platforms •SAR •cargo	•oil platforms •disaster relief •cargo •logging •construction •firefighting •commuter (30 pax) •cargo	•commercial transport (90-120 pax) •disaster relief •civil reserve aircraft fleet (CRAF) •cargo
	autonomous capability				
Configura-tions	 				 

blue highlight: new mission and/or new configuration

Technologies for Spectrum of Missions and Configurations

	Configurations (Definition follows DOD convention for rotorcraft)				
	Very Light	**Light**	**Medium**	**Heavy**	**UltraHeavy**
Missions	•surveillance •delivery •spraying •cargo	•police •training •traffic/ news •power line service •spraying •cargo	•police •EMS •traffic/news •tourism •executive •charter •oil platforms •SAR •cargo	•oil platforms •disaster relief •cargo •logging •construction •firefighting •commuter (30 pax) •cargo	•commercial transport (90-120 pax) •disaster relief •civil reserve aircraft fleet (CRAF) •cargo
	autonomous capability				
Technology Investments	•autonomous and airspace-related technologies •sensors •batteries	•weight •speed •safety	•payload •SFC •green	•range •noise	

blue highlight: new mission and/or new configuration

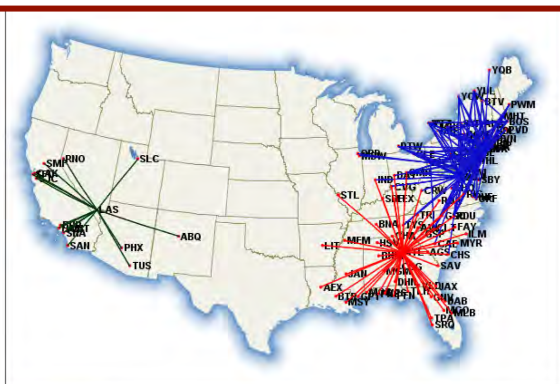
NASA RW decision:
Highlight the mission that has the strongest potential to benefit the airspace system and technologies that benefit to the widest range of configurations.
Working UltraHeavy configuration is high-risk, high-payoff.

	Very Light	Light	Medium	Heavy	UltraHeavy
Missions	•surveillance •delivery •spraying •cargo	•police •training •traffic/ news •power line service •spraying •cargo	•police •EMS •traffic/news •tourism •executive •charter •oil platforms •SAR •cargo	•oil platforms •disaster relief •cargo •logging •construction •firefighting •commuter (30 pax) •cargo	•commercial transport (90-120 pax) •disaster relief •civil reserve aircraft fleet (CRAF) •cargo
	autonomous capability				
Technology Investments	•autonomous and airspace-related technologies •sensors •batteries	•weight •speed •safety	•range •noise	•payload •SFC •green	

System Study Results

Recent System Studies:

- NASA Heavy Lift/ Large Civil Tiltrotor (LCTR2)
- Future Concepts in the NextGen
- Technology Benefit Assessment for Compound and Tiltrotor Systems
- Tiltrotor Fleet Operations in the NextGen



Status/Results

- Vertical capability at one or both ends of a 300-600nm mission increases airport capacity.
- Large, advanced technology tiltrotors consistently outpace other configurations in the ability to meet transportation mission
- Advanced technologies give tiltrotors cost and operational parity with configurations already in use
- **In latest 3 studies (2010, 2011) Civil tiltrotors show capability to improve airspace system performance significantly; identified technical barriers to overcome**

Technologies for Spectrum of Missions and Configurations

NASA decision: Working these technologies because they have a broad range of applications. Getting most bang for the buck while providing focus on revolutionary technologies.

Configurations

(Definition follows DOD convention for rotorcraft)

Light	Medium	Heavy	UltraHeavy
•police •training •traffic/ news •power line service •spraying •cargo	•police •EMS •traffic/news •tourism •executive •charter •oil platforms •SAR •cargo	•oil platforms •disaster relief •cargo •logging •construction •firefighting •commuter (30 pax) •cargo	•commercial transport (90-120 pax) •disaster relief •civil reserve aircraft fleet (CRAF) •cargo

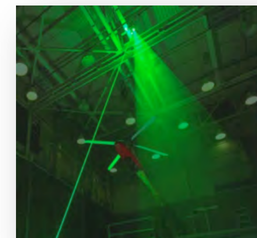
autonomous capability

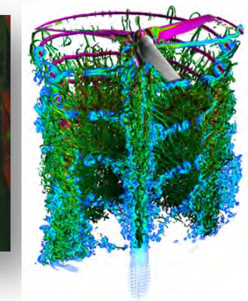
•weight	•payload	•range
•speed	•SFC	•noise
•safety	•green	

Challenges for Future Rotorcraft

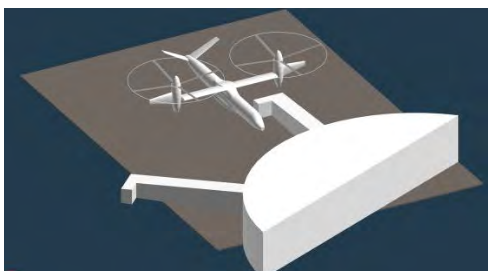
Active Rotor Systems

Modeling and Validation

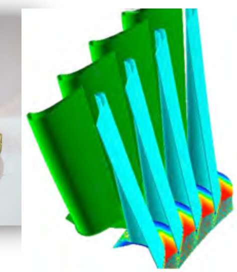


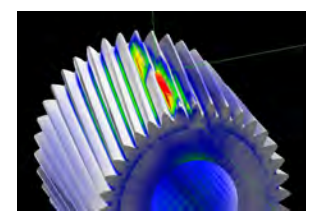


NextGen Integration

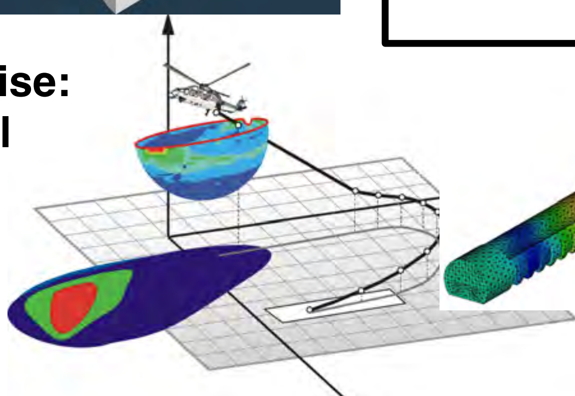


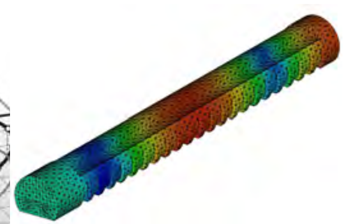
Propulsion System

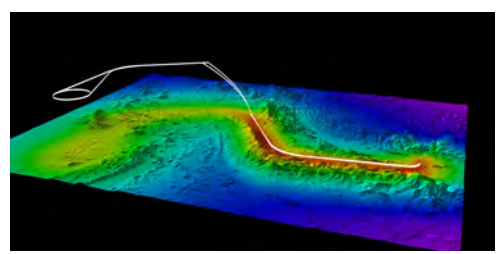




Low Noise: External and Internal







Technology Benefit Study

Study Objective: assess technologies that have significant benefit for Single Main Rotor Compound (SMRC) and Civil Tiltrotor (CTR) configurations

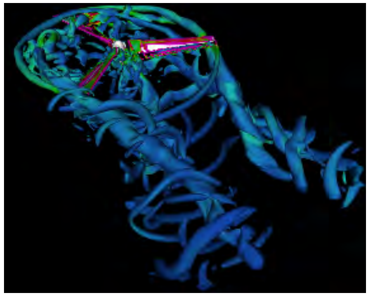
- Conducted by Boeing under NASA contract
- Results published: NASA Contractor Report 2009-214594
- Metric: Direct Operating Cost per Available Seat Mile (DOC/ASM)

Results: Most beneficial categories (benefit amount depends on the configuration)

- Engine fuel flow
- Structural weight
- Drive system weight
- Parasite drag
- Rotor hover and cruise performance

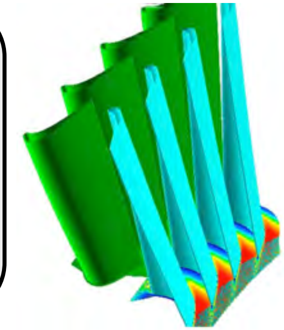
Investment in these technologies provides benefit to both compound and tiltrotor configurations

FY13 RW Key Elements/Areas of Research



FY13 SRW Project Summary*

~95 work/years (78 CS / 17 Contractor)
~ $24M per year (includes salary)
Host is LaRC



Ames Research Center
~30 work/years

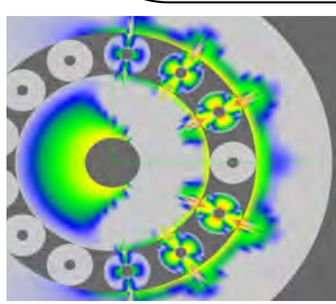
- Aeromechanics
- CFD
- Flt Dyn & Ctrl
- Exp Capability
- System Analysis

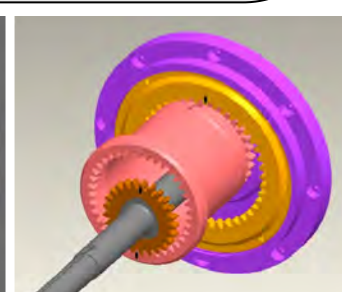
Glenn Research Center
~33 work/years

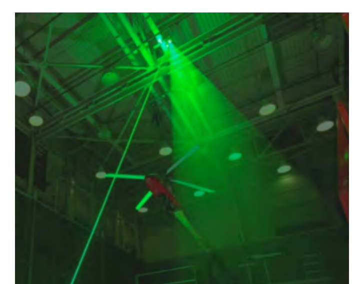
- Drive Systems
- Engines
- Icing
- System Analysis
- CBM

Langley Research Center
~32 work/years

- Acoustics
- Aeromechanics
- Exp Capability
- CFD
- Crashworthiness







*based on FY13 President's budget

SRW Major Facilities

FY13 SRW Project Summary*

~95 work/years (78 CS / 17 Contractor)
~ $24M per year (includes salary)

Ames Research Center

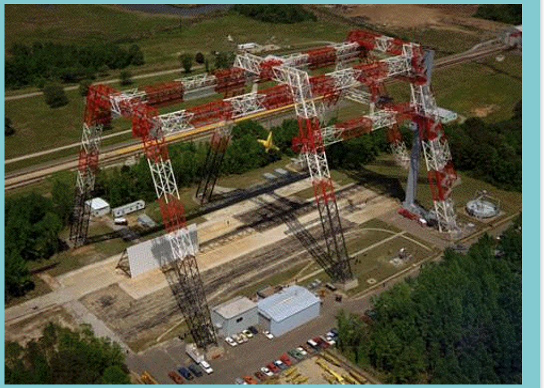
- National Full-Scale Aerodynamics Complex (NFAC)
- Supercomputing Complex (NAS)
- Vertical Motion Simulator

Glenn Research Center

- Compressor Test Facility (CE-18)
- Linear cascade test facility (W22)
- Transmission Test Facilities (ERB)
- Icing Research Tunnel

Langley Research Center

- 14- by 22-Foot Subsonic Tunnel
- Transonic Dynamics Tunnel
- Landing and Impact Research



*based on FY13 President's budget

RW Research Approach

Three main paths to accomplish research:

- NASA in-house research
- Research with partners (Other Government Agencies, Industry, Universities)
- Sponsored research proposals through NASA Research Announcement (NRA)

Glenn Research Center

NASA AMES Platinum Jubilee 70

NASA Langley 90th Anniversary

U.S. ARMY

DARPA

DEPARTMENT OF THE NAVY UNITED STATES OF AMERICA

Liberty Works **Sikorsky** **DLR**

Boeing **VLC** **Bell** **UTRC**

ONERA **Bombardier** **Williams**

GT

PENNSTATE 1855

UNIVERSITY OF MARYLAND 1856

Key Technical Areas

Technical Challenges

- Demonstrate variable speed power turbine with 50% improvement in efficiency lapse rate over wide operating speed
- Demonstrate two-speed drive system with less than 2% power loss while maintaining current power-to-weight ratios
- Quantify performance, noise and vibration benefits of 3 Active Rotor concepts by test and analysis
- Demonstrate 35% improvement in accuracy of predictions for rotor loads and performance for both hover and forward flight.

Additional Areas of Emphasis

- Demonstrate technologies required for community and passenger acceptance of large rotorcraft operating in the National Airspace (NAS)

NASA Propulsion Technology Investment

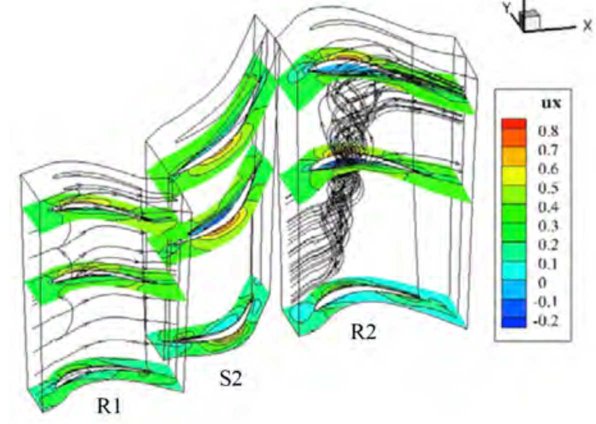
Advanced Efficient Propulsion

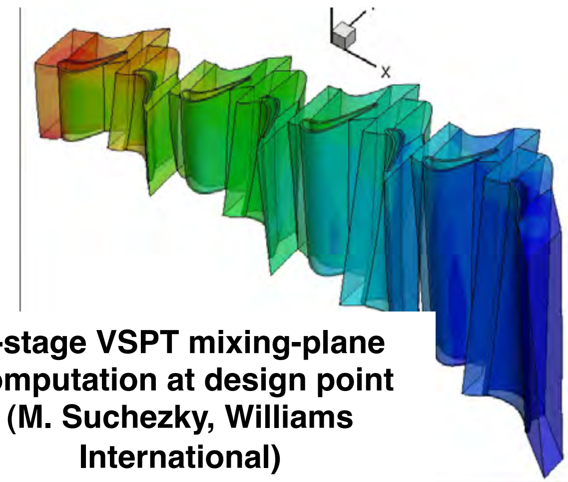
- **Variable speed turboshaft engines**
  - **Variable speed power turbine**
  - **High efficiency gas generators**
- Multi-speed lightweight drive systems
  - Advanced gearbox components and configurations
  - Variable speed transmission
  - Condition based maintenance

Variable-speed power turbine (VSPT)

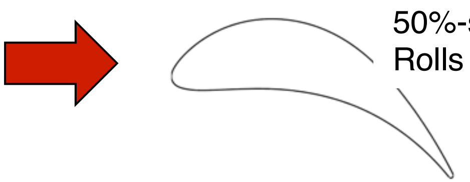
- Conceptual & 3-D blade design/analysis (in-house)
- Assessed in-house paths to VSPT component test
- Down-selected Walters-Leylak transition model for RANS tools
- Transonic linear cascade facility modified; testing of incidence-tolerant blade set complete
- Rotordynamics evaluated
- Rolls-Royce and Williams Int. RTAPS contracts completed
- Collaboration with Army Aviation Applied Technology Directorate (AATD); exploring applicability to FATE-class engines

4-stage of VSPT at takeoff





4-stage VSPT mixing-plane computation at design point (M. Suchezky, Williams International)



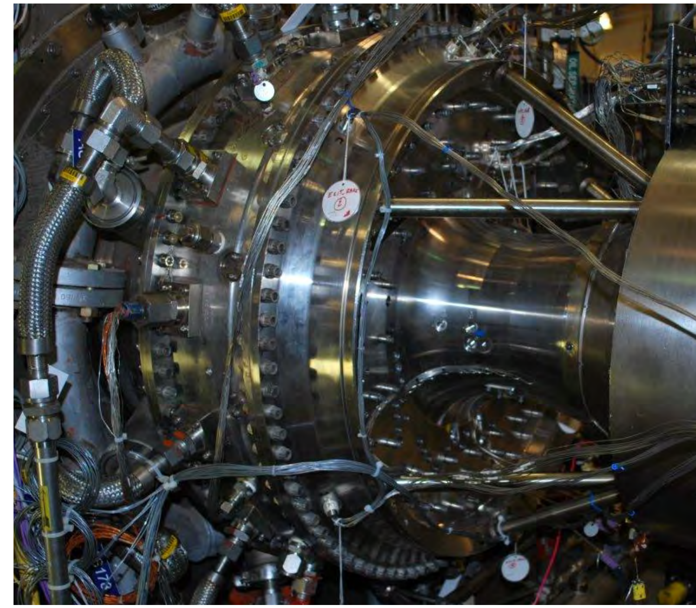
50%-span section
Rolls Royce Liberty Works

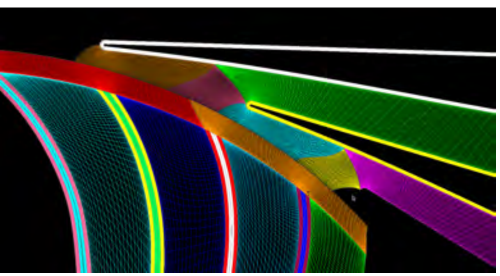
Incidence-tolerant blading
First entry in CW-22

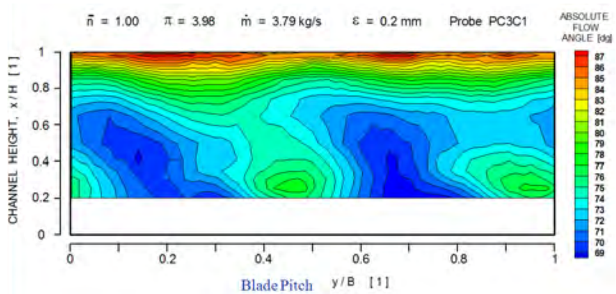
Significance: New innovative concept to enable efficient, wide-range turbine operation.

High Efficiency Centrifugal Compressor (HECC)

- Pre-test grid-generation and URANS CFD (CC3 & HECC) completed; post-test CFD on-going
- High-response p0-probe developed
- Completed detailed mapping of HECC compressor in CE-18. Data collected at corrected speed lines between 55% and 104%, at multiple impeller-to-shroud tip-gap settings.







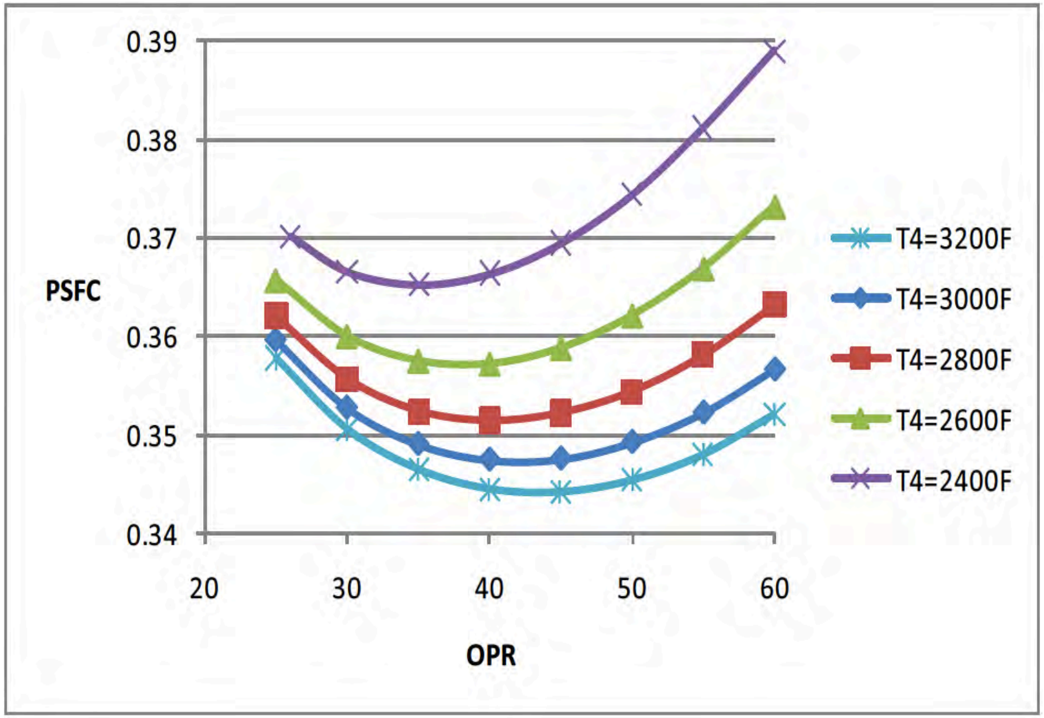
Flow angle from high-response p0 probe data

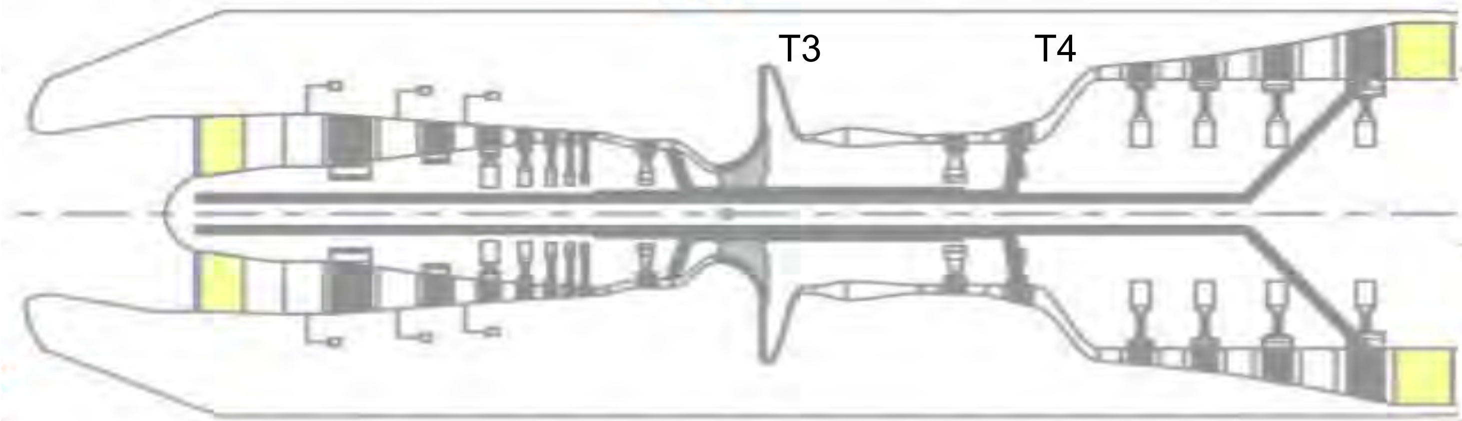
Significance: Knowledge gain will advance the SOA compressor technology to enable new lighter weight/high efficiency compressor needed to power the next generation of variable speed rotors

(cost-shared effort with UTRC)

Engine cycle studies

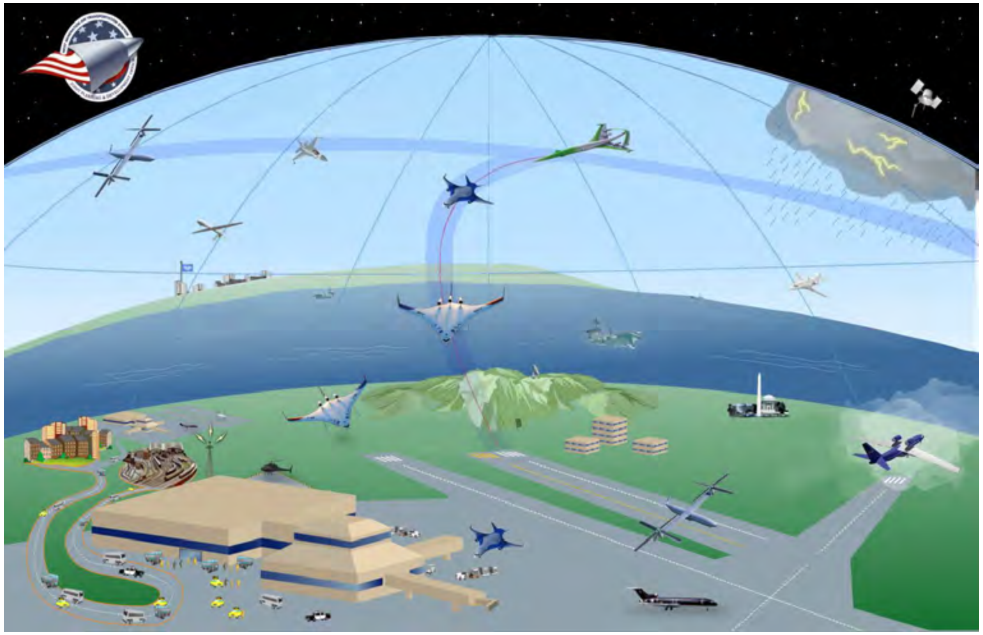
- Current work on TBC's and CMC's addresses the need for higher T4
- Recent studies indicate that fuel burn continues to improve with OPR ~45 and T4~3200.
- Impeller technologies needed to achieve the required OPR (higher T3) are being considered





Concluding Remarks

- RW is focused on high-risk, high-payoff area with strong ties to National and NASA Aeronautics Goals
- Investment in technologies is broadly applicable to wide range of configurations and missions
- Partnerships (DOD, industry, university) are key to many research areas
- Future vision of civil airspace includes rotorcraft as essential piece of transportation system





NASA